

***Interactive comment on* “Brief Communication:  
Evaluation and comparisons of permafrost map  
over Qinghai-Tibet Plateau based on inventory of  
in-situ evidence” by Bin Cao et al.**

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Received and published: 31 October 2018

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## Response to Anonymous Referee #1

### Anonymous Referee #1

Received and published: 17 October 2018

The authors would like to thank the reviewer for the constructive feedback, and the thorough assessment of the manuscript. Below we provide a point-to-point response to each comment, reviewer comments are given in black, responses are given in blue. Additionally, we have included details of how we intend to address these changes in a revised submission.

Permafrost maps were released by various institutes or research teams during the past several decades. They used modeling, statistical, and other mapping techs. Basically, the maps were evaluated during processing. However, the inter-comparison, what this study was done, is required for better understanding. This study collected more than a thousand samples over the QTP. The results of this study would be useful for future permafrost studies on the QTP and broad interest to the permafrost communities.

The manuscript, however, requires a bit more work before it is acceptable for publication. For the most part, the manuscript is well written but some editing is required to improve language and increase clarity. There are a few places in the manuscript

where more explanation would be helpful.

[Response: The language of revised manuscript will be carefully checked.](#)

Although I have made a few comments here that I hope the authors will find useful, dealing with them may not take too much time. The authors should thoroughly proofread the revised manuscript before submission or invite a native speaker in permafrost communities to improve the language. I am willing to review the revised paper.

### Major:

- **Unclear description and logic (to the following results) in the Data and Methods section.**

The authors used four methods to classify permafrost or not. However, it's not enough for understanding, although this paper is a short communication.

– How deep are generally for boreholes and soil pits? 1 m, 5 m?

[Response: In general, the borehole depths vary from meters to hundred meters. In this study, we used the mean annual ground temperature from boreholes, which also varies from several meters to about 20 m, to identify permafrost presence. Number of samples measured from soil pits was small \(6 samples\) due to the prevalent coarse soil, and their depths are between less than 1 m to about 2.5 m. In the revised manuscript, we will add](#)

*[“In this study, we used the mean annual ground temperature \(MAGT\) measured from boreholes, which varies from meters to about 20 m to identify permafrost presence or absence. Due to the prevalent coarse soil, SP was only applied in](#)*

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*areas possible, and the depth is from less than 1 meter to about 2.5 m.”*

to clarify.

Additionally, the survey depth of all the methods will be summarized in Table A1 (see below)

## TCD

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**Table A1.** Classification algorithm of in-situ permafrost presence or absence evidence from various methods

<i>Method</i>	<i>Indicator</i>	<i>Survey depth</i>	<i>Permafrost</i>	<i>Confidence degree</i>
<i>BH</i>	$MAGT \leq 0$	meters to about 20 m	presence	high
<i>SP</i>	ground ice presence	about 1.0–2.5 m	presence	high
<i>GST</i>	$MAGST \leq -2 \text{ }^\circ\text{C}$ & observations $\geq 3$	0.05 or 0.1 m	presence	medium
	$MAGST \leq -2 \text{ }^\circ\text{C}$ & observations $< 3$		presence	low
	$MAGST > -2 \text{ }^\circ\text{C}$ & $MAGST + TO_{max} \leq 0 \text{ }^\circ\text{C}$		presence	low
	$MAGST < 0 \text{ }^\circ\text{C}$ & $MAGST + TO_{max} > 0 \text{ }^\circ\text{C}$		ambiguous	–
	$MAGST > 0 \text{ }^\circ\text{C}$		absence	medium
<i>GPR</i>	clear permafrost reflection	about 0.80–5.0 m	presence	medium

*BH* = borehole temperature, *SP* = soil pit, *GST* = ground surface temperature, and *GPR* = ground-penetrating radar.  $TO_{max}$ , the maximum thermal offset under natural conditions reported for the QTP, is 0.79 °C.

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– It looks like this study used only  $MAGST + TO_{max} \leq 0$  as the standard. In your results, you only talked about the sites considered as permafrost. I am not sure whether these classifications (P2, L25-29) are necessary.

Response: As mentioned by Referee #2 (specific comment Page 2, line 18), the word “certainty” is changed to “confidence”. Yes, the confidence classifications were not further used in this manuscript, but only present in the inventory as supplement. Since the inventory may be useful for other researches, we would keep the classification in the inventory and move the classification description into the Appendix A (see below). We hope you agree.

The classification algorithm of confidence degree largely follows Cremonese et al. (2011) and could be summarized as

*“Appendix A: Classification algorithm of in-situ permafrost presence or absence evidence*

*For board use of the permafrost presence or absence inventory, the data confidence degree was provided (Table A1). BH and SP provide direct evidence of permafrost presence or absence based on MAGT and/or ground ice observations, and hence have high confidence (Cremonese et al., 2011). The data confidence derived from MAGST is classified based on temperature and the length of the observation period. The evaluated GPR survey result was considered as medium confidence.”*

– What is kind of antennas generally used in GPR survey? Also, how deep is accessed?

Response: The GPR survey was conducted using 100 and 200 MHz antennas and evaluated using direct measurements (e.g., mechanical probing, soil temperature, and soil pits) (Cao et al. , 2017). The survey depth was from about 0.8

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to near 5 m depending on the active layer thickness. In the revised manuscript, authors will add

*“Here, GPR data from (Cao et al. , 2017) are measured using 100 and 200 MHz antennas depending on the active layer thickness. The GPR survey depth is from about 0.8 to near 5 m, and the data are considered as indicating the presence of permafrost only if an active layer thickness (or a clear permafrost reflection) could be established.”*

to clarify.

– In section 2.3, you used DEM (3 arc second), MAAT (1 km), MASCD (~500 m), and NDVI (~250 m). I guess you extract those variables for each site in your inventory. Is it?

Response: First of all, it is moved to Section 2.2 as Referee #2 suggested. Yes. We extract these variables to sample sites using nearest interpolation. We will add

*“These climate variables were extracted to in-situ sites/plots based on nearest interpolation.”*

to clarify.

You also said (P5, L2-4) "Where original field evidence of permafrost presence/absence is located within the same grid cell (30 arcsec, 1 km), they were aggregated based on their major value. For a grid with one permafrost site and one non-permafrost site, the nearer site from the grid center was used to

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represent the grid." (actually, these sentences should be moved to section 2.3). Why did you have to aggregate these in-situ data to 1 km?

**Response:** Yes, they are located within the same grid cell of unprojected SRTM30 with a spatial resolution of 30 arcsec. The aggregation will be deleted in the revised manuscript.

How did you deal with DEM, MASCD, and NDVI? Did you upscale DEM, MASCD, and NDVI to 1 km? I guess you were going to avoid conflict sites (permafrost and non-permafrost) in the same pixel. Is it?

**Response:** No. The 3 arcsec DEM was used to simulate the slope and aspect for the in-situ sites. The MASCD, NDVI, and MAAT are used here to explore the representative of the inventory, and they are extracted to the sites based on nearest interpolation.

When you extracted values from different spatial resolution datasets, even if there are probably few sites in the same pixel at 1 km resolution, however, there still are three spatial datasets with higher resolution, which might bring different snow, topography, and vegetation condition to your sites. In fact, there might be different ground thermal states under the same climate and vegetation condition because of different soil wetness, soil properties, and so on. Overall, I don't think the aggregation is necessary.

**Response:** Yes, we agree. In the revised manuscript, we will omit the evidence aggregation and conduct the evaluation with all the 1475 sites. Please note that, some statistics may be slightly different by using the original 1475 evaluation sites/plots.

Furthermore, how did you compare with the maps with different spatial scale, e.g., QTP<sub>Noah</sub> map is 10 km. Those issues were confusing and should be

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clarified.

Response: The evaluation was conducted at the sites we collected. Permafrost presence and absence information at evaluation sites was extracted to the evidence based on nearest from different maps. In Section 2.4 Statistics and evaluation of permafrost distribution maps, we will add

*“The permafrost and absence information was extracted to in-situ sites, and. . .”*

to clarify.

- Misleading indicators.

$PCC_{PF}$ ,  $PCC_{NPF}$ , and  $PCC_{tol}$  were used to quantify the classification accuracies of permafrost maps. To my sense,  $PCC_{PF}$  and  $PCC_{NPF}$  are not useful and may be misleading. When the map over-presents permafrost (i.e., much colder),  $PCC_{PF}$  would be extremely close to 100%. Can we say this is much better? Vice versa. Thus, the description in Section 3.2 could be misleading, at least to me, and should be more cautious. I suggest removing those parts.

Response: Yes, we agree that  $PCC_{PF}$  and  $PCC_{NPF}$  are somehow misleading when we look at them separately without due care. On the other hand, these two indicators would be useful if they are jointly interpolated. As you mentioned, the high  $PCC_{PF}$  together with low  $PCC_{NPF}$  indicate the map over-presents permafrost. This information could not be indicated by either kappa coefficient nor  $PCC_{tol}$ . For this reason, we would keep these three indicators. To avoid the misunderstanding, the  $PCC_{PF}$  and  $PCC_{NPF}$  are interpolated together throughout the manuscript, and the over- or less-presents permafrost was also present. Additionally, the  $PCC_{tol}$  in Figure 2 will be deleted to avoid confusion. In

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the revised manuscript, we will add

*"The high  $PCC_{PF}$  together with  $PCC_{NPF}$  for the IPA,  $QTP_{Noah}$ ,  $PZI_{cold}$ , and  $QTP_{TTOP}$  maps indicate permafrost is over-presented by them, while the  $PZI_{warm}$  and  $PZI_{norm}$  showed underestimated the permafrost over the QTP."*

Meanwhile, do you consider the effect of the different sample volume? Because in your in-situ sites pool, number of sites with permafrost is twice as large as the sites without permafrost.

Response: Yes, the kappa coefficient, *"which measures inter-rater agreement for categorical items"*, was introduced here as the major indicator for map evaluation as it could largely *"avoid the impact of uneven distribution of sample numbers for permafrost presence and absence"*.

- More discussion?

This study found different performance in permafrost maps. It's better to discuss a little bit more about the sources of bias, such as different MAAT products. More discussion on the possible sources of the revealed differences would enhance the scientific significance. Meanwhile, it also is useful for the future permafrost map updating.

Response: Yes, we agree. Our previous manuscript had partly discussed the bias from inputs for the  $QTP_{Noah}$  and IPA maps. In the revised manuscript, we will enhance this part, and the inputs bias will be discussed for each map as below:

$QTP_{Noah}$  map: *"Though the  $QTP_{Noah}$  map was derived using coupled land surface model (Noah), the relatively worse performance, especially for non-permafrost area ( $PCC_{NPF} = 45.9\%$ ), is likely caused by inputting coarse-scale forcing dataset ( $0.1^\circ$  resolution or  $\sim 10$  km) (Chen et al., 2011) and by the*

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*uncertainty of soil texture dataset (Yang et al., 2010)."*

*IPA map: "It is not surprising that the IPA map has fair agreement ( $k = 0.32$ ) as less observations were compiled and the method used are more suitable for high latitudes (Ran et al., 2012)."*

*QTP<sub>TTOP</sub> map: "The QTP<sub>TTOP</sub> map was derived based on MODIS land surface temperature with different temporal coverage of 2003–2012 (Zou et al., 2017). Though the MODIS land surface temperature time-series gaps caused mainly by cloud were filled using the Harmonic Analysis Time-Series (HANTS) algorithm (Prince et al., 1998), the surface conditions, especially vegetation and snow cover, were ignored. In this case, land surface temperature is underestimated in high and/or dense vegetation area as it comes from the top of vegetation canopy, and is overestimated in snow covered area due to the cooling effects of snow is not considered. As a consequence, permafrost is likely overestimated in high and/or dense vegetation area and underestimated in regular snow-covered area."*

*PZI<sub>global</sub> map: "The MAAT used in the PZI<sub>global</sub> map was statistical downscaled based on the lapse rate from the upper-air (or pressure level) temperature of NCEP, but the influences of land surface on surface air temperature, such as cold air pooling, was ignored (Cao et al., 2017). This is important as winter inversion is expected to be common due to the prevalent mountains over the QTP. In other words, permafrost may be underestimated in valleys due to the overestimated MAAT."*

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- P1, title: the title could be "Ground-based evaluation and inter-comparisons of permafrost maps over the Qinghai-Tibet Plateau"?

Response: We will change the title to

*"Evaluation and inter-comparisons of permafrost map over the Qinghai-Tibet Plateau based on inventory of in-situ evidence".*

As the study also provided the first inventory of permafrost presence or absence over the Qinghai-Tibet Plateau based on in-situ evidence, authors would like to reflect the inventory in the title. I hope you agree.

- P1, L3: the number, 1475, might be misleading although you collected. Because you aggregated to 1040, which excluded about 400 sites. Add a comma to 1040/1475 for consistency.

Response: The aggregation part is removed, and evaluation was conducted using all the data.

- P2, L1: "hemisphere" → hemispheric ?

Response: Corrected.

- P2, L10: "2000" → "the 2000s"?

Response: Corrected.

- P2, L16: insert "survey" after GPR.

Response: Done.

- P2, L25-29: Where is so-call "high certainty" for permafrost classification? Meanwhile, it looks like this study used only  $MAGST + TO_{max} \leq 0$  as the standard. I am not sure whether these classifications are necessary. If necessary, the authors should clarify.

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Response: As the Referee #2 mentioned, the word “certainty” is changed to “confidence”. The evidence derived from BH and SP is considered as high confidence as they provide direct information, such as mean annual ground temperature or ground ice presence. Yes. To determine permafrost presence or absence, only the function of  $MAGST + TO_{max} \leq 0$  was used. The confidence classifications were not used in this manuscript, but only present in the inventory as supplement. Since the inventory may be used for other related studies (e.g., permafrost simulation evaluation), and the confidence information would be useful for further selecting the data, we would keep the classification in the inventory and move the classification description into the Appendix A. Please also see our response to the major comments of "Unclear description and logic".

- P3, L1: The authors should briefly clarify what kind of antennas were used and how deep is accessible.

Response: In the revised manuscript, the author will add

*“Here, GPR data from Cao et al., (2017) are measured using 100 and 200 MHz antennas depending on the active layer thickness. The GPR survey depth is from about 0.8 to near 5 m, and the data are considered as indicating the presence of permafrost only if only an active layer thickness (or a clear permafrost reflection) could be established.”*

to clarify.

- P3, Section 2.2: It’s worth to note what climate data were used in  $QTP_{TTOP}$  and  $QTP_{Noah}$  maps. Both used the data merged MODIS temperature products and station data?

Response: As we mentioned in the previous submission,

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*"The most recent efforts were made by Zou et al. (2017) using the mean annual temperature at the top of permafrost (TTOP) model (referenced as QTP<sub>TTOP</sub> map) forced by land surface temperature (or freezing and thawing indices) considering soil properties, and by Wu, Nan, Zhao, Zhao, Cheng, (2018) based on Noah land surface model (referenced as QTP<sub>Noah</sub> map) as well as gridded meteorological dataset (e.g., surface air temperature, radiation, and precipitation)"*

The land surface temperature used in the QTP<sub>TTOP</sub> map was calibrated based on ground observations or the station data, but only grid data was used by the QTP<sub>Noah</sub> map. We will change this sentence to

*"The most recent efforts were made by Zou et al. (2017) using the mean annual temperature at the top of permafrost (TTOP) model (referenced as QTP<sub>TTOP</sub> map) forced by **calibrated (using station data)** land surface temperature (or freezing and thawing indices) considering soil properties, and by Wu, Nan, Zhao, Zhao, Cheng, (2018) based on Noah land surface model (referenced as QTP<sub>Noah</sub> map) as well as gridded meteorological dataset, **including surface air temperature, radiation, and precipitation.**"*

to clarify.

- P3, L6: "(1)" → "(i)"  
Response: Done.
- P3, L7: "(2)" → "(ii)"  
Response: Done.

- P3, L11: "... the temperature at ..." → "...the mean annual temperature at..."  
Response: Done.
- P4, L5: "... outline of QTP ..." → "...outline of the QTP..."  
Response: Done.
- P4, L24: Is the calculation of "Cohen's kappa coefficient" too complicated? If not, please put equation(s) here and indicate what a high k means. Is there some threshold to roughly classify good, fair, or others?  
Response: "Cohen's kappa coefficient" equations will be added as

$$\kappa = \frac{p_o - p_e}{1 - p_e} \quad (1)$$

*"where  $p_e$  and  $p_o$  are the probability of random agreement and disagreement, respectively, can be calculated as"*

$$p_e = \frac{(PF_T + PF_F) \times (PF_T + NPF_F)}{(PF_T + PF_F + NPF_F + NPF_T)^2} \quad (2)$$

$$p_o = \frac{(NPF_F + NPF_T) \times (PF_F + NPF_T)}{(PF_T + PF_F + NPF_F + NPF_T)^2} \quad (3)$$

Authors will remove the kappa coefficient threshold description from footnote of Table 1 to this section.

*"Cohen's kappa coefficient result is interpreted as excellent agreement for  $k \geq 0.8$ , substantial agreement for  $0.6 \leq k < 0.8$ , moderate agreement for  $0.4 \leq k < 0.6$ , fair agreement for  $0.2 \leq k < 0.4$ , and slight agreement for  $k < 0.2$ ."*

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- P5, L12-13: What's Qxx?  
Response: Did not see "Qxx".
- P5, L15: Cao et al. (?), missing year.  
Response: It will be revised to "Cao et al. (2018)".
- P6, L14: why is "-3 to -4 °C"? Generally, -4 to -3 °C?  
Response: It will be revised to -4 to -3 °C.

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